THE IMPLEMENTATION OF ANTHROPOMETRIC MEASUREMENT IN DESIGNING THE ERGONOMICS WORK FURNITURE

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Abstract

The productivity of an employee has a crucial role for the company. The higher the level of productivity, the higher the profit they can provide for the company. Ergonomic furniture is one of the supporting examples in increasing employee productivity. Designing ergonomic furniture is the effort taken by the company to boost the employee's productivity. The ergonomic furniture can provide comfort to the employee and minimize the occurrence of Musculoskeletal Disorders (MSDs). The provided coziness will increase the level of concentration so that the performance of the employee will be increased too. The existence of ergonomic furniture will offer benefits to the company. Therefore, companies are required to provide adequate facilities and infrastructure to support employee activities. One of the company's facilities is a table and chairs. Tables and chairs must be designed ergonomically, considering that both facilities will continually be used within 8 hours per day. This research aims to utilize anthropometric measurement as a design tool for ergonomic work furniture. The anthropometric measurement was conducted on 85 employees and used 11 body dimensions as a parameter. These body dimensions consist of a supine hand, sitting, forward pinch-grip reach, elbow height, shoulder width, pelvic width, buttock-knee length, knee height, shoulder height, sitting, length of elbow to toe, thigh clearance, and palm width. The 5th percentile was used for four dimensions in this research, while the rest used 95th. The results of this research are expected to minimize the possibility of various health problems caused by the un-ergonomic working furniture so that the employee's performance will be improved too.

Keywords: ergonomic, ergonomic design, anthropometry, anthropometric measurements, work furniture, ergonomic furniture, body dimensions.

1. Introduction

Ergonomics refers to a process for designing or modifying workplaces, products, or services according to a human comfort level. One of the main goals of ergonomics is to improve performance and reduce fatigue. The ergonomic process includes a method for evaluating work, studying how the body responds to the demands of the job and using this information to design or create work areas to meet these goals [1]. Besides, in order to meet these goals, designing the work area and the equipment becomes the important thing to do. According to [1], the design of the work area and the equipment used has a significant effect on worker fatigue, performance, and occupational health and safety.

The basic philosophy of ergonomics is to create work equipment and working areas that provide comfort, physical health and safety [1]. On the other side, Reddy [2] stated that the major objective of the ergonomics application are to provide the workstation that fits with the users' anthropometry so that it will create a natural working posture. Both of this literature argued that adopting the ergonomics concept is needed in the designing process. Minimizing the occurrence

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of musculoskeletal disorders (MSDs) is one of the reasons why adopting ergonomic designs is important. MSDs are mainly due to the wrong body posture and prolonged sitting [2]. In Indonesia, employees are required to conduct their job for more than 7 hours, where almost all of the time is spent sitting in their chairs. This prolonged sitting has been done daily repetitively. Therefore, it can increase the occurrence probability of MSDs.

MSDs are injuries or pain in the joints of the body, muscles, ligaments, tendons, nerves, and structures that support the legs, back, and neck [3]. In the long term, MSDs which are degenerative diseases and inflammatory conditions, can cause pain and interfere the normal activities of employees [4]. Besides, it is reported that MSDs result in discomfort, aches, and pain in all over the body and increase the risk of disc herniation [1]. Moreover, [5] claimed that designers have paid a little attention to the ergonomic principles in a couple of years while designing their products. Considering the effect of MSDs, it is necessary to take preventive measures to reduce the impact resulting from the design of tables and chairs that are not ergonomic.

Tables and chair are the furniture which is used mainly by the employees. As stated above, an employee spent their time in the desk for more than 7 hours in a sitting position. Those activities have been done daily and in repetitive. In the long term, the poor posture in sitting accompanied with the poor design of furniture may lead to the increasing of MSDs [4]. Adopting the concept of ergonomics in designing the furniture means minimizing those effects. Besides, the ergonomic intervention in the designing process not only focuses on the health-related problems but also improves the employees' productivity [6].

Anthropometric measurements can be considered as a tool for designing working tables and chairs so that the employee comfortability will increase, minimize the occurrence of musculoskeletal disorders (MSDs), and improve employee performance in conducting their job [5]. Anthropometric measurement is the process of measuring the physical dimensions and mass properties of the human body. This measurement needs to be done in designing furniture to determine the size of the human body. In addition, the purpose of this measurement is to provide accurate data so that the provided design will be appropriate [6]. This research was conducted in one of the manufacturing companies located in Malang. This research aims to create an ergonomic design of working tables and chairs using anthropometric measurements to increase employee productivity.

2. Materials and Methods

There are several methods that can be applied in adopting the concept of ergonomics for the designing process [7] use Rapid Entire Body Assessment (REBA) and Rapid Upper Limb Assessment (RULA) to assess the working posture and design the machine using Quality Function Deployment (QFD). Meanwhile, [8] combine the method of REBA and RULA with Analytical Hierarchy Process (AHP) to minimize the risk of using the press machine. The use of REBA and RULA in the designing process is considered a powerful tool to assess the current working posture. Besides, it is also known for its simplest, easiest, and quickly complete [7]. On the other side, [9, 10] use anthropometry measurements to design ergonomic furniture. Anthropometry measurement is an appropriate thing to do in the designing process since nowadays the varieties of the human body are different, and even most of them could be categorized as plus-size [11].

The ergonomic design is not a design for the average person, but the design should be for the 95th percentile, which means that 95 % of the population can use it. The design process should consider many factors, such as the anthropometric data. Anthropometry is a process of measuring the human body's mass properties and its physical dimension. Collecting the anthropometric data is a complicated process and also time-consuming since it has to do the measurement traditionally using a measuring device. On the other side, [9] proposed some challenges to designing the product. Those challenges are as follows:

1. The design must be for all, which is means the design should be used for as much as a user.
2. The one-size design that fits for all.
3. Made to fit the users body size and shape.
4. The design should be for average, which means many people can be excluded from comfortable usage.

The changes in lifestyles, the nutrition and food consumed, and the changing population lead to the changes of body dimensions distributions so that it requires updating the anthropometric data collection [1]. Therefore, anthropometry data is essential to design ergonomics products, and it varies from one person to another. Besides, anthropometry has a significant role in industrial design, ergonomics, architecture, etc.

This research was a based case study undertaken in one of the manufacturing companies located in Malang. Hence, anthropometric measurement is used to design the ergonomics infrastructure that consists of tables and chairs. The measurement began with measuring the body dimension of the employees. The total number of employees considered in this research was 85, consisting of 62 male employees and 23 female employees. Meanwhile, the total body dimension used as a parameter was 11. In this research, the data used was an employee body dimension that was taken conventionally using a measurement device. Data collection was carried out based on 11 predetermined body dimensions. The explanation regarding the used body dimensions can be seen in **Table 1**.

Table 1

The used body dimensions

No.	Dimension	Explanation
1	D23	Supine hand, sitting
2	D26	Forward pinch-grip reach
3	D4	Elbow height
4	D15	Shoulder width
5	D16	Pelvic width
6	D11	Buttock-knee length
7	D14	Knee height
8	D8	Shoulder height, sitting
9	D19	Length of elbow to toe
10	D9	Thigh clearance
11	D22	Palm width

Anthropometric measurement can be combined with other methods or can be used as a single approach. It can be used as a tool to design an ergonomics office chair. The data collection that consists of the necessary dimensions suitable for the chair was taken into account [6]. Furthermore, the anthropometric data will be tested with normality, uniformity, and adequacy test. The aim of this test is to analyze whether the data can be used for the next calculation. After the data analysis was done, the researcher came up with complete dimensions for the new design. The recommendation of dimensions for table and chair includes the height of bench surface, the depth and width of bench, the width, height, and angle of backrest, the height of the desk, the depth, width, and angle of the desk.

The ergonomics design has significant impacts on human health. The un-ergonomics design of the product will cause pain in the back, neck, shoulder, and muscle. Besides, it may cause leg joint pain and also pain in the wrist and elbow. When the pain is repetitive in the long term, it may become severe. All those problems could be minimized by designing an ergonomic product. The work furniture is an example of a product that must be designed ergonomically. The work furniture that consists of a table and chair is responsible for the comfortability in conducting activities [3]. The previous research stated that the seat depth and thigh length mismatch are significantly related to the sitting discomfort. Besides, a mismatch of the height of seated elbow and desk height also has significant relations with the shoulder and neck pain. The reviewed literature indicates that anthropometric parameters are one of the important factors in deriving and designing the comfortable furniture for both adults and workers [9].

There is several data analysis that was conducted in this research. Firstly, the normality test using Kolmogorov-Smirnov in SPSS. Secondly, the uniformity test using Microsoft Excel and lastly calculate the 5th, 10th, 50th, 90th, and 95th percentile then propose the ergonomic design. **Fig. 1** shows the step of this research.
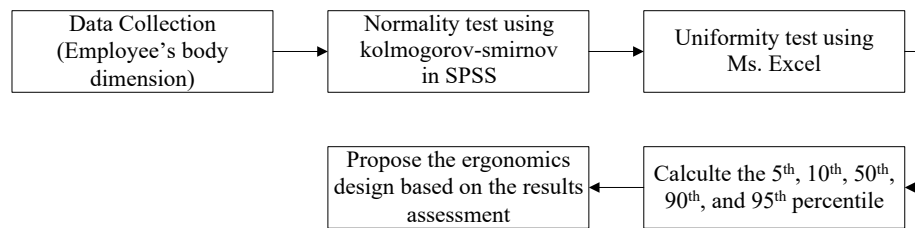
Fig. 1. Step of the research

3. Results and Discussion

The data analysis included the normality test using SPSS, uniformity test using Microsoft Excel, and percentile calculations in this research. In its application, the adequacy test was not carried out in this research because the generated data was assumed to be sufficient. After the normality test is carried out, the next step is to conduct the uniformity test by determining the upper and lower limit values, making an anthropometric table, and calculating the percentile. **Table 2** will show the output of the normality test using SPSS software.

Table 2 shows that the distribution of male body dimension is normal since the value of Asymptotic Significance (2-tailed) is more than 0.05 ($\alpha = 0.05$). Furthermore, **Table 3** shows the normality test results of female body dimensions.

Table 2

The output of normality test of male body dimension using SPSS

One-Sample Kolmogorov-Smirnov Test											
–		D23	D26	D4	D15	D16	D11	D14	D8	D19	D9	D22
	N	62	62	62	62	62	62	62	62	62	62	62
Normal Parameters[a,b]	Mean	173.350	88.727	102.692	44.300	38.282	58.326	43.285	60.924	45.676	22.2218	11.248
	Std. Deviation	8.2171	85.1752	4.2479	3.4753	4.7710	5.0219	2.7920	5.5474	4.4250	3.28210	21.5353
Most Extreme Differences	Absolute	.095	.465	.064	.209	.089	.103	.133	.167	.224	.091	.491
	Positive	.095	.465	.064	.103	.082	.074	.133	.167	.162	.079	.491
	Negative	−.060	−.392	−.052	−.209	−.089	−.103	−.104	−.150	−.224	−.091	−.399
Test Statistic		.095	.465	.064	.209	.089	.103	.133	.167	.224	.091	.491
Asymp. Sig. (2–tailed)		.200[c,d]	.000[c]	.200[c,d]	.000[c]	.200[c,d]	.098[c]	.008[c]	.000[c]	.000[c]	.200[c,d]	.000[c]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

Table 3

The output of normality test of female body dimension using SPSS

| One-Sample Kolmogorov-Smirnov Test											
–		D23	D26	D4	D15	D16	D11	D14	D8	D19	D9	D22
	N	23	23	23	23	23	23	23	23	23	23	23
Normal Parameters[a,b]	Mean	159.387	69.935	93.396	39.100	36.348	56.978	38.743	55.183	40.865	21.909	7,665
	Std. Deviation	7.4889	4.3278	4.8177	2.3283	3.6039	2.3953	3.6077	2.4086	2.6036	2.7300	.8266
Most Extreme Differences	Absolute	.141	.119	.105	.132	.128	.100	.146	.140	.132	.118	.149
	Positive	.141	.099	.105	.132	.128	.075	.146	.095	.132	.118	.149
	Negative	−.106	−.119	−.077	−.092	−.073	−.100	−.103	−.140	−.076	−.093	−.104
Test Statistic		.141	.119	.105	.132	.128	.100	.146	.140	.132	.118	.149
Asymp. Sig. (2-tailed)		.200[c,d]	.200[c,d]	.200[c,d]	.200[c,d]	.200[c,d]	.200[c,d]	.200[c,d]	.200[c,d]	.200[c,d]	.200[c,d]	.200[c,d]

a. Test distribution is Normal.
b. Calculated from data.
c. Lilliefors Significance Correction.
d. This is a lower bound of the true significance.

As well as the normality test results on the male body dimensions, the normality test results in women also show that the data used has a normal distribution. Therefore, these data can be used for the next test, the uniformity test using Microsoft Excel. **Fig. 2** shows the uniformity test results in the dimensions of supine hand, sitting.

a   *b*
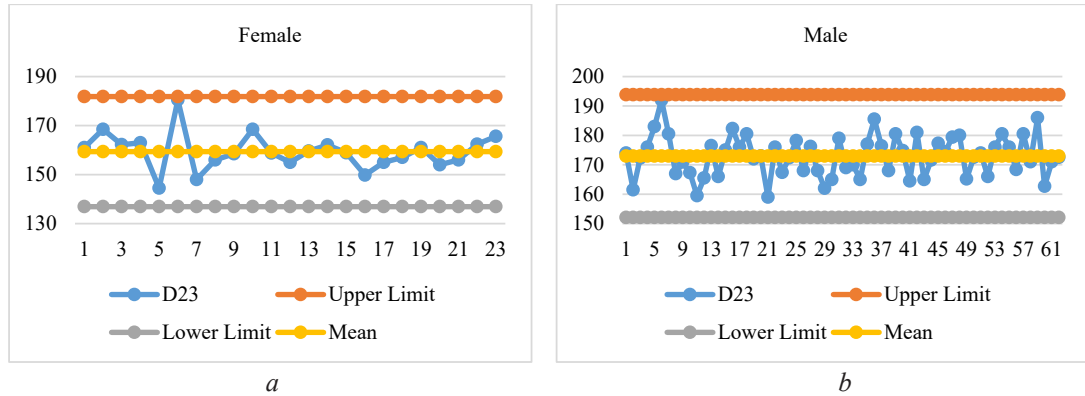
Fig. 2. The output of uniformity test using Microsoft Excel: *a* – control chart of female body dimensions; *b* – control chart of male body dimensions

In this paper, the parameter of x axis is measurement results for each dimension that used as a reference. Meanwhile, the y axis includes the value of the upper limit, lower limit, and mean. The figure shown in **Fig. 2** is an example of the uniformity test results for the 23rd male and female dimensions. The results of the uniformity test indicate that the collected data in the 23rd dimension does not exceed the upper and lower limit values. So that it can be concluded that the data on the 23rd dimension is uniform. This applies to the first dimension, supine hand, sitting, and to the rest of the dimensions. The calculation of the uniformity test of the data shows that all data are stated uniformly, so there is no need to dispose of the extreme data that is out of the upper and lower control limits. The last step of data analysis is calculating the percentile of those data. Percentile calculation aims to determine whether the percentage of a population is equal to or below this measure. The percentiles used in this research are 5th, 10th, 50th, 90th, and 95th percentile. **Table 4** shows the results of percentile calculations.

Table 4

The results of percentile calculations of male body dimension

Dimension	Mean	Std Deviation	Percentile				
			5th	10th	50th	90th	95th
D23	172.9629	6.954541714	161.5227	164.0611	172.9629	181.8647	184.4031
D26	88.72742	85.17523147	−51.3858	−20.2969	88.72742	197.7517	228.8407
D4	102.6919	4.247903953	95.70413	97.25462	102.6919	108.1293	109.6797
D15	44.3	3.475252084	38.58321	39.85168	44.3	48.74832	50.01679
D16	38.28226	4.771002719	30.43396	32.17537	38.28226	44.38914	46.13056
D11	58.32581	5.021917062	50.06475	51.89775	58.32581	64.75386	66.58686
D14	43.28548	2.791958404	38.69271	39.71178	43.28548	46.85919	47.87826
D8	60.92419	5.547431409	51.79867	53.82348	60.92419	68.02491	70.04972
D19	45.67581	4.424954774	38.39676	40.01186	45.67581	51.33975	52.95486
D9	22.22177	3.282100249	16.82272	18.02069	22.22177	26.42286	27.62083
D22	11.24839	21.53529122	−24.1772	−16.3168	11.24839	38.81356	46.67394

Table 4 shows the value of the mean, standard deviation, and also percentile calculations for each used female body dimension. These calculations will apply to both female and male body dimensions. **Table 5** shows the results of percentile calculations of male body dimensions.

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In determining the dimensions of the design, several equations are needed based on the anthropometric approach. This is related to determining the use of the 5th percentile and 95th percentile. The use of percentiles in calculations is adjusted according to the category. Spatial dimensions use large percentiles, while reach dimensions use small percentiles [10].

The proposed design is made based on the measurement results of the body dimensions and the results of the previous calculation of percentiles. This determination aims to be able to produce products that are suitable for the size of the largest user population. Therefore, the design is expected to be more ergonomic and optimize the employee's productivity. **Table 6** provides an explanation of the dimensions and the percentiles that will be used in the design.

Table 5

The results of percentile calculations of male body dimension

Dimension	Mean	Std Deviation	Percentile				
			5th	10th	50th	90th	95th
D23	159.387	7.488858655	147.0678	149.8012	159.387	168.9727	171.7061
D26	69.93478	4.327775903	62.81559	64.39523	69.93478	75.47434	77.05397
D4	93.39565	4.817720912	85.4705	87.22897	93.39565	99.56233	101.3208
D15	39.1	2.328284581	35.26997	36.1198	39.1	42.0802	42.93003
D16	36.34783	3.603895565	30.41942	31.73484	36.34783	40.96081	42.27623
D11	56.97826	2.395252221	53.03807	53.91234	56.97826	60.04418	60.91845
D14	38.74348	3.607671887	32.80886	34.12566	38.74348	43.3613	44.6781
D8	55.18261	2.408630726	51.22041	52.09956	55.18261	58.26566	59.14481
D19	40.86522	2.603600426	36.58229	37.53261	40.86522	44.19783	45.14814
D9	21.9087	2.729953886	17.41792	18.41435	21.9087	25.40304	26.39947
D22	7.665217	0.826607907	6.305447	6.607159	7.665217	8.723276	9.024987

Table 6

The dimension and percentiles used in the design

No.	Dimension	Explanation	Percentiles	Size	Allowance	Total
1	D23 Supine hand, sitting	The table width	5, Male	161.52	5	166.52
2	D26 Forward pinch-grip reach	The table length	5, Female	62.815	5	67.815
3	D4 Elbow height	The table height	5, Male	95.7	5	100.7
4	D15 Shoulder width	The drawer width	95, Female	42.93	2	44.93
5	D16 Pelvic width	The chair width	95, Male	46.13	2	48.13
6	D11 Buttock-knee length	The chair length	95, Male	66.58	2	68.58
7	D14 Knee height	The chair height	95, Male	47.87	5	52.87
8	D8 Shoulder height, sitting	The back of the chair	95, Male	70.04	5	75.04
9	D19 Length of elbow to toe	The armrest length	95, Male	52.95	1	53.95
10	D9 Thigh clearance	The armrest height	5, Male	16.82	3	19.82
11	D22 Palm width	The armrest width	95, Female	46.67	1	47.67

Table 6 indicates that the percentiles used for the design were 5th and 95th. The determination of the percentiles was customized with its category. In the first number, the chosen percentiles for 23rd dimension are 5th of the male dimension, it means that the table can be used by other users who have the higher percentiles value. Moreover, the 23rd dimension is meant to give the exact size of the table width used in the designing process. The given total in **Table 4** is the sum from the size and the allowance. Those calculations are applied for all the dimensions assessed. On the other side, some of the dimensions also use the 95th percentile, which is means 95 % of users can comfortably use that product, while the 5 % may need to be accommodated [1]. Besides, adding an allowance is necessary and an additional measure of impact factor of clothing thickness that

must be worn by the operator [11]. Moreover, the allowance of a shoe should be considered too for the design of the chair when the measurement was taken barefoot [9]. **Fig. 3** is the proposed design that has been made based on the results of calculations.
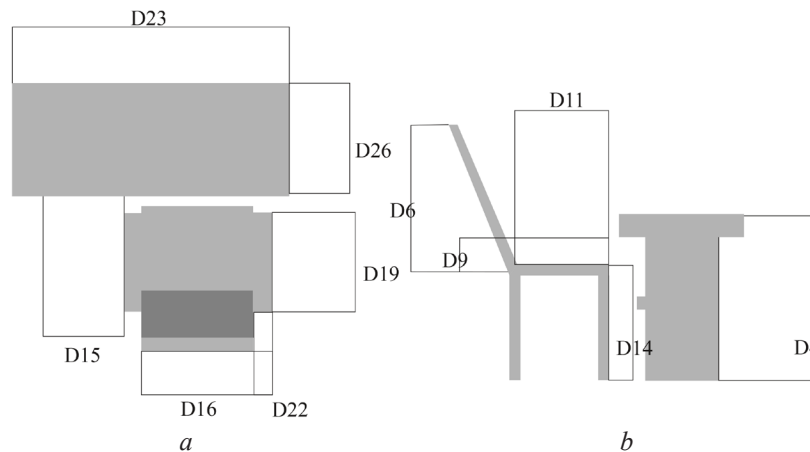
Fig. 3. The proposed ergonomics tables and chair design:
a – the design is seen from above; *b* – the design is seen from the side

Fig. 3 shows an image of a table and chair design that has been made based on the dimensions selected in **Table 4**. The dimensions used are the results of percentile calculations from anthropometric data that have been obtained previously. Furthermore, the results are summed up with the allowance, and so on will be used as a reference in determining the size of the design. The design used in this research is a pure design based on the results of anthropometric calculations without paying attention to other aspects. This can be used as a gap for further research to pay more attention to other aspects, for example, an aesthetic aspect.

The existence of this design is expected to contribute to the company so that it can pay attention to the details of anthropometric measurements in the process of procuring tables and chairs in the future. Considering the important relationship between ergonomic furniture design and employee performance, it needs to be done. This is closely related to the statement of [12], which states that to create a good performance, the process of eliminating MSDs pain is one thing that must be done. In addition, the company must consider minimizing the risk of injury to improve work performance [12].

This research is far away from perfection, this is due to the focus of this research is to carry out anthropometric measurements and carry out the design process without paying attention to other aspects. This is because there is an agreement between the company and the author that their main concern is how to improve the performance of workers through an ergonomic desk and chair design. Recalling the close relationship between furniture design and employee performance further strengthens our reason for putting aside other aspects and focusing on the anthropometric measurement and ergonomic design. Therefore, in the future research, it might be better if the proposed design considered the aesthetic aspect and also could be formed into a prototype or 3D picture so that it will be easier to understood. This kind of research should be done frequently in the future so that we can have enough anthropometric databases.

4. Conclusions

This research uses 11 main dimensions that are used as parameters in formulating an ergonomic table and chair design. These body dimensions consist of supine hand, sitting, forward pinch-grip reach, elbow height, shoulder width, pelvic width, buttock-knee length, knee height, shoulder height, sitting, elbow to toe, thigh clearance, and palm width. The measurement of these predetermined dimensions was carried out for both male and female employees. The proposed ergonomic tables and chair design was generated from the percentile calculation. The 5th percentile

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was used for four dimensions in this research, while the rest used 95th. The selection of these percentiles is adjusted based on their category.

These ergonomics tables and chairs are designed to increase the comfort level of employees while using this furniture so that the employee's productivity will be increased too. Besides, this design can be used as a reference to create ergonomic products. For further research, it might be better if the proposed design considered the aesthetic aspect and also could be formed into a prototype or 3D picture so that it will be easier to understand. This kind of research should be done frequently in the future so that we can have enough anthropometric databases.

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